GEODETIC SURVEY WORK OF HIGH INTENSITY PROTON ACCELERATOR FACILITY

Kenji Mishima[*], *PASCO Corporation, Tokyo, Japan*
Norio Tani, Japan Atomic Energy research Institute, Tokai village, Japan

1. INTRODUCTION

The High Intensity Proton Accelerator Facility, which is refers to as "J-PARC" project (Japan Proton Accelerator Research Complex), is constructing at the Tokai campus of JAERI, about 130 kilometres northern east of Tokyo in Japan. This facility is constructed as joint project of the Japan Atomic Energy Research Institute (JAERI) and the High Energy Accelerator Research Organization (KEK).

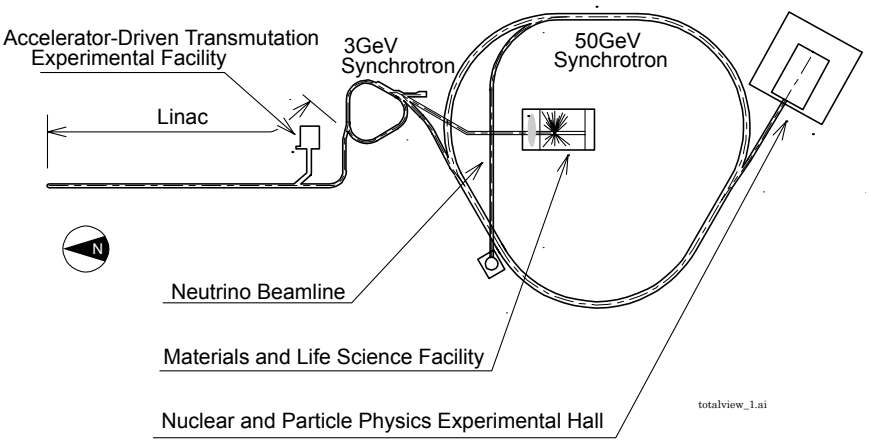


Fig. Schematic view of this facility

This accelerator complex consist of following accelerators (see Fig.1) :
(1) 400 MeV normal conducting Linac,
(2) 600 MeV superconducting Linac to increase the energy from 400 to 600MeV,
(3) 3 GeV synchrotron ring, which provides proton beams at 333 mA (1 MW), and
(4) 50 GeV synchrotron ring, which provides proton beam at 15 mA (0.75 MW).

These accelerators are located on the extensive area about 1000 meters to north and south, and about 500 meters to east and west (see Fig. 2).

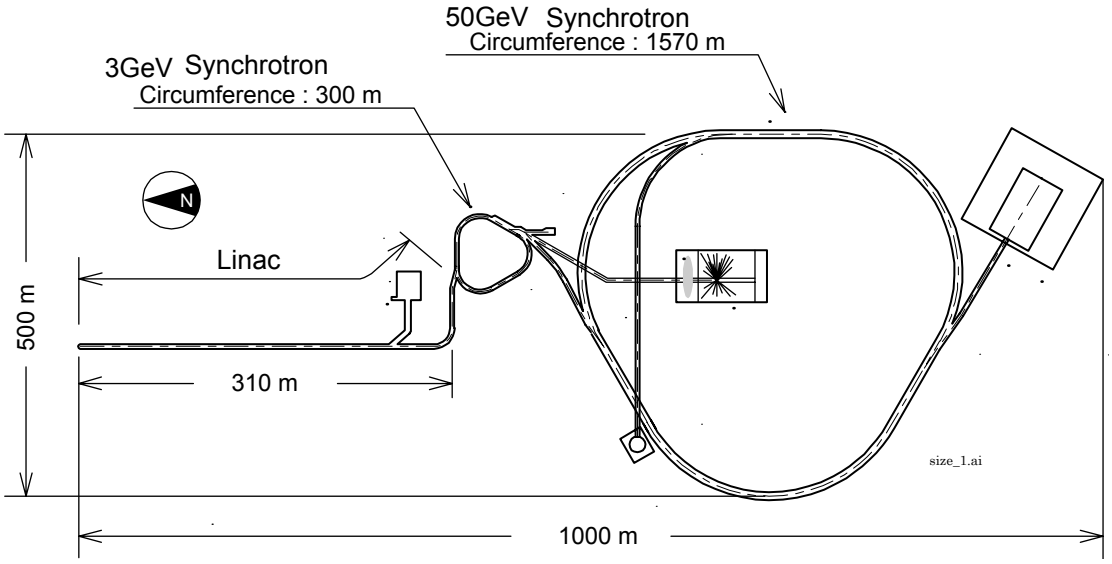


Fig.2 Approximate dimension of accelerators

Especially, one of many experiments by the 50 GeV proton synchrotron is the neutrino oscillation using the Super-Kamiokande as a detector. The distances from this J-PARC to the Super-Kamiokande are 300 kilometres. Therefore, this is a huge machine about 300 kilometres to east and west (see Fig.3 at the next page). Consequently, survey works must consider the curvature of the earth.

This report presents geodetic survey works of J-PARC.

2. NECESSITY FOR HIGH ACCURATE SURVEY AT THE J-PARC

The start of final alignment for these accelerators is the year of 2006. J-PARC must solve some difficulties in geodetic surveying until then.

2.1. Correlation between Super-Kamiokande and J-PARC

Neutrino beam from J-PARC is shot toward Super-Kamiokande (see Fig.3 at the next page). So, it is to say that J-PARC is the huge accelerator stretching over 300 kilometres. Therefore, the surveying has some difficulties to derivate from the size and curvature of the earth.

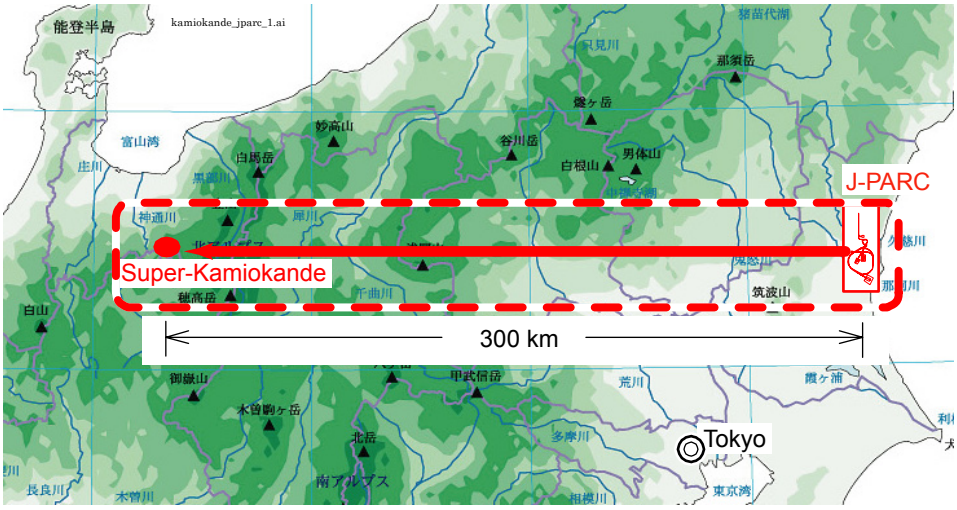


Fig.3 Schematic view of Super-Kamiokande and J-PARC (1)

When J-PARC will be correlated with Super-Kamiokande, the direction of the nozzle for the neutrino beam line from J-PARC toward Super-Kamiokande is described by the plane of rectangular coordinate system (see Fig.4). Therefore, the surveying these angles are difficult by longitudes and latitudes or terrestrial coordinate system ITRF.

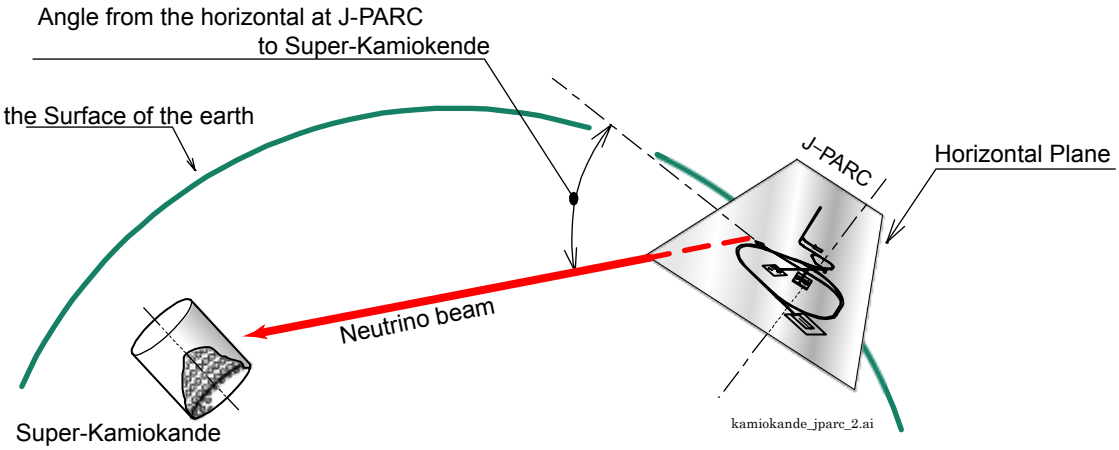


Fig.4 Schematic view of Super-Kamiokande and J-PARC (2)

2.2. Large accelerator

The size of J-PARC is about 1000 meters from north to south, and about 500 meters from east and west (see Fig.2). The circumference of the 3 GeV is 300 meters, and the circumference of the 50 GeV is 1570 meters. Therefore, the surveying in the Tokai campus also is considered the curvature of the earth.

2.3. Easy to maintenance

After several years to drive these accelerators, these tunnels will have strong radioactivity. Therefore, re-alignment for the maintenance will have to align within the least time what the surveyors can.

3. COUNTERMEASURES FOR THESE PROBLEMS

3.1. Correlation between Super-Kamiokande and J-PARC

In Japan, 1200 GPS stations what are called the Electronic Survey Control Point have been placed by the Geographical Survey Institute (see Fig.5). These Electronic Survey Control Points were placed about every 30 kilometres. The extensive survey network from J-PARC to Super-Kamiokande has been constituted by these Electronic Survey Control Points (see Fig.11). Thus, J-PARC complex has been correlated with the Super-Kamiokande complex. The coordinates of both complexes are described by longitudes and Latitudes on the ellipse Global Reference System (GRS) 80 which is the Japanese national standard, not on the ellipse World Geodetic System (WGS) 84 which is GPS using. And, another description on the reference system is International Terrestrial Reference Frame (ITRF) 94 of the Geocentric three dimensional reference system.

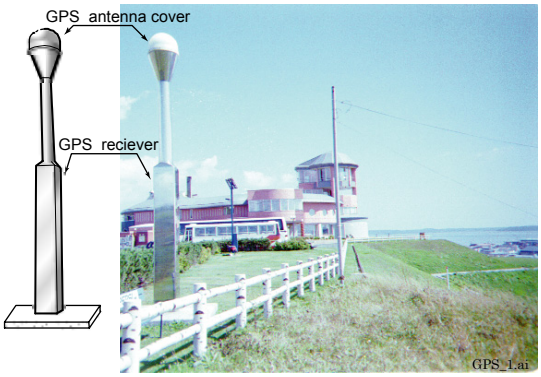
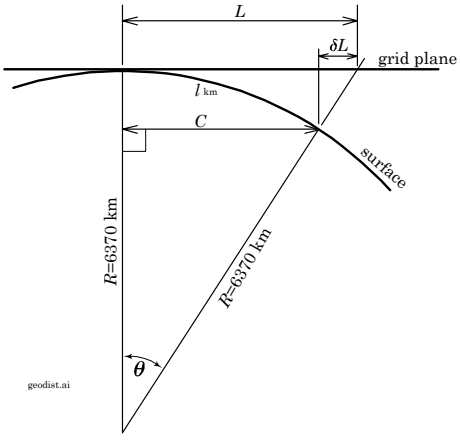


Fig.5 Electronic Survey Control Point

3.2. Large scale accelerator

3.2.1. Effect of curvature for horizontal distances



$$\theta = \frac{l}{R} = \frac{1000\ \mathrm{m}}{6370\ \mathrm{km}} \quad (1)$$

$$C = R\sin\theta \quad (2)$$

$$L = R\tan\theta \quad (3)$$

$$\delta L = L - C \quad (4)$$
$$= 1.24 \times 10^{-5}$$
$$= 12.4\ \mu\mathrm{m}$$

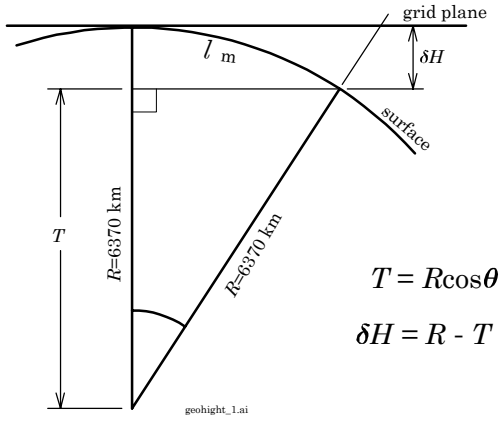
Fig.6 Effect of curvature for horizontal distance

The effect of the curvature of the earth for horizontal distances is 12 micrometers when measured 1 km (see Fig.6). The most accurate Electronic Distance Meter (EDM) which can measure long distances is the MEKOMETER ME5000. But this small difference can not measure by this EDM. Therefore, the effect of the curvature of earth for horizontal distances can neglect in J-PARC.

3.2.2. Effect of curvature for heights

Table.1 effects of curvature for height

l [m]	δH [mm]
50	0.20
100	0.79
200	3.15
300	7.08
500	19.66
1000	78.64



$$T = R\cos\theta \quad (5)$$

$$\delta H = R - T \quad (6)$$

Fig. 7 Effect of curvature for heights

The curvature of the earth affects for the height (see Table.1 and Fig.7). High accurate levelling instruments (for example N3, NA3003 and so on) can measure 0.1 millimetres. Therefore, the curvature of the earth is considered when components of the accelerator are aligned. Standards of horizontal planes are set to 3 major parts in J-PARC (see Fig.8).

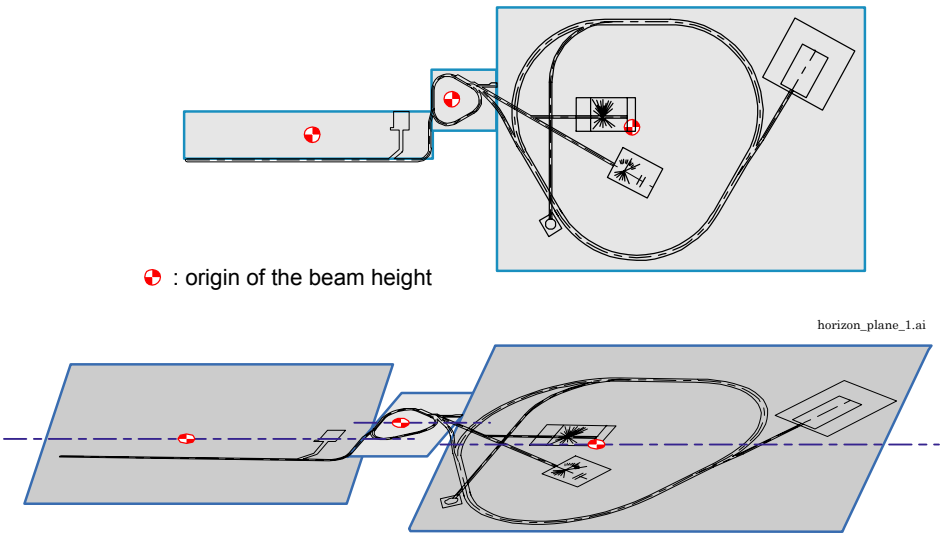
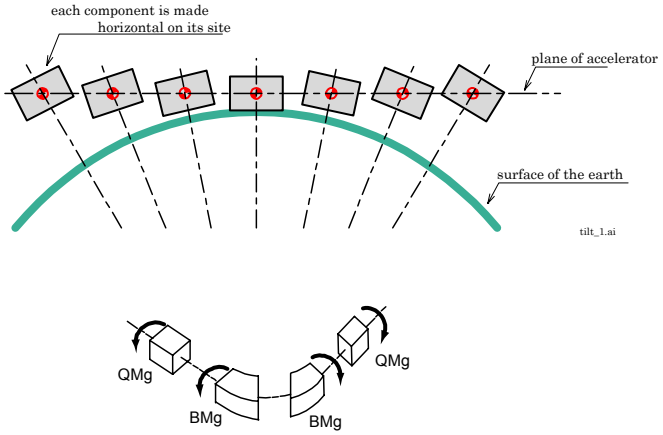


Fig.8 Standards of horizontal planes

3.2.3. Tilt of each component on its horizontal plane



Although components of accelerator are aligned for pitching and rolling of each component at its point, these components have not been aligned at the view of out from this accelerator. Because the each horizontal plane is different (see Fig.9 and 10). These tilts depend on the radius of accelerator, and they are shown in Table 2.

Fig. 9 effect of curvature for tilt

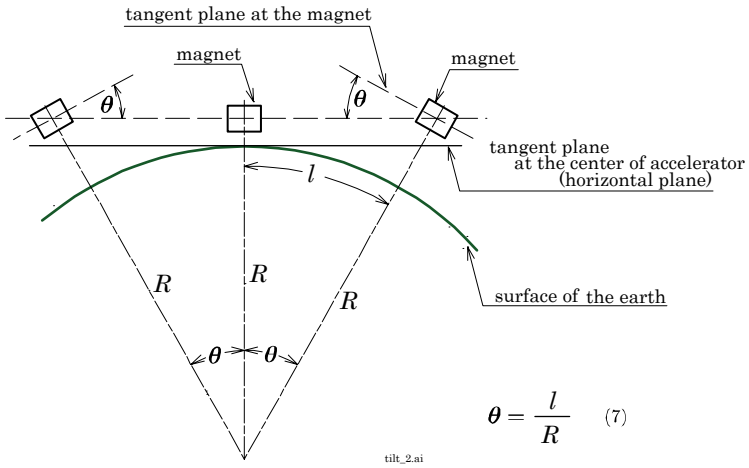


Fig. 10Tilt angle for horizontal plane at a component

Table 2 Tilt of components by the radius of accelerator

Radius of accelerator l [m]	Tilt angle θ [mrad]
10	0.00
50	0.01
100	0.02
200	0.03
300	0.05

The biggest accelerator in J-PARC is 50 GeV synchrotron. As the radius of this synchrotron is about 260 meters, the tilt angle is 0.04 milliradians. The goal of accuracy for pitching and rolling is 0.1 millimetre per 1 meter (0.1 mrad). Therefore, it is possible to neglect to the tilt of components at there sites.

4. SURVEY WORKING

First of all, the out frame survey network from J-PARC to Super-Kamiokande whose distance is 295 kilometres has been surveyed via Electronic Survey Control Points. Therefore, J-PARC complex has been correlated with the Super-Kamiokande complex. The accuracy of this survey and each monument is described by error ellipses (see Fig.11). These error ellipses are within 2 or 3 millimetres.

Although J-PARC has been woody area, 1st order monuments in J-PARC cannot have been surveyed by optical survey instruments. These have been surveyed by GPS. The error ellipses of this survey are shown in Fig.12. These error ellipses are within 2 or 3 millimetres.

These 1st order monuments are surveyed twice in February, 2003 and February, 2004. Displacements of 1st order monuments are shown in Fig.13. Some monuments displaced by construction of accelerator tunnels from year of 2003 to year of 2004.

5. CONCLUSION

As components of these accelerators will be aligned in October, 2006, 1st order survey work is monitor for the deformation of the land in J-PARC.

The forest in J-PARC is lumbering now. Therefore, parts of 1st order monuments can be surveyed by high accurate optical survey instruments for example MEKOMETER ME5000. The result of this survey will be reported by using new survey instrument and new survey network in next work shop.

References

[1] Kenji Mishima, PASCO, “Survey and Alignment Plan of High Intensity Proton Accelerator Facility, 1st Survey Report” (in Japanese), Feb. 2003

[2] Kenji Mishima, PASCO, “Survey and Alignment Plan of High Intensity Proton Accelerator Facility, 2nd Survey Report” (in Japanese), Feb. 2004

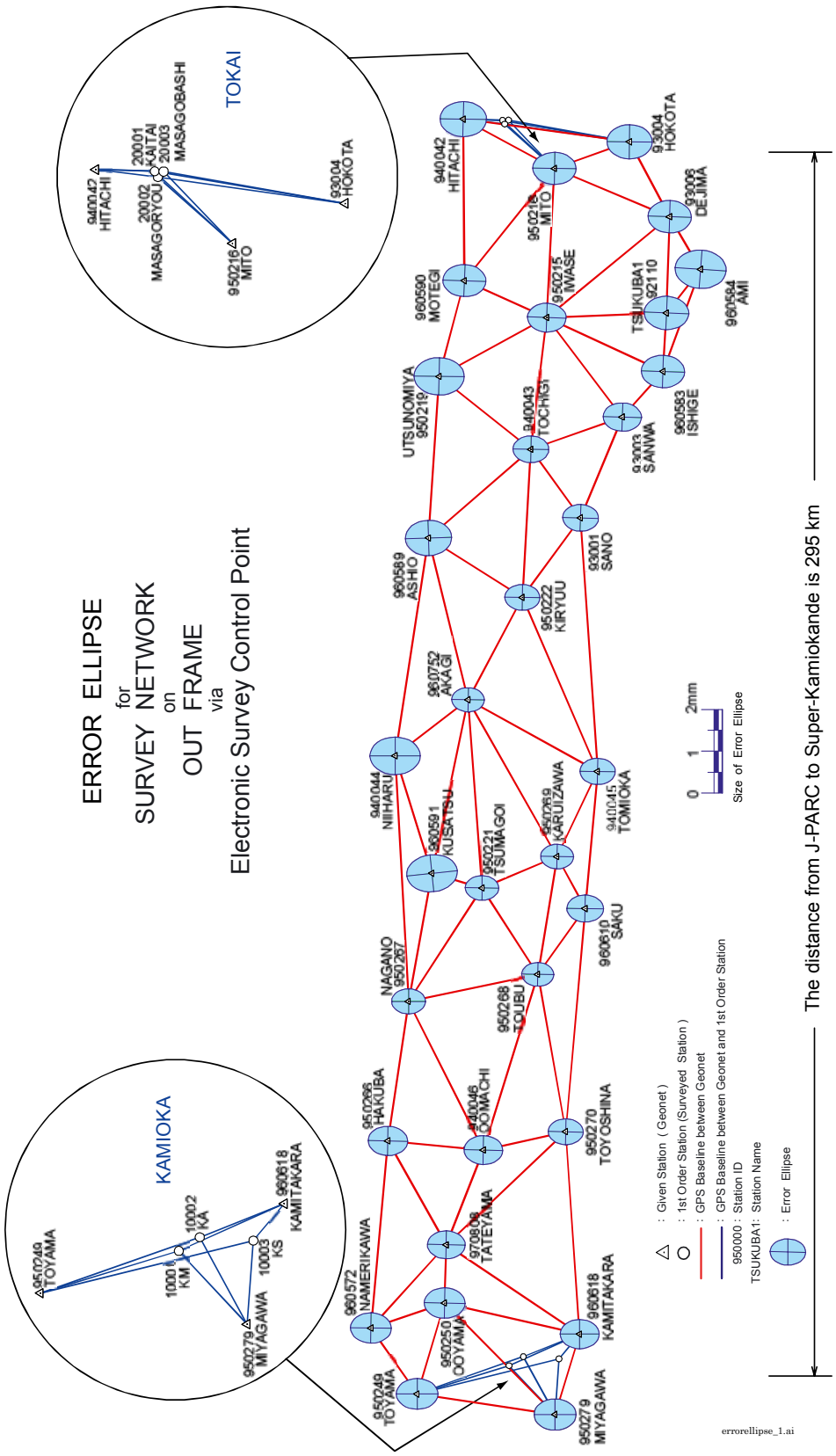


Fig.11 Error ellipse of Out Frame toward Super-Kamiokande

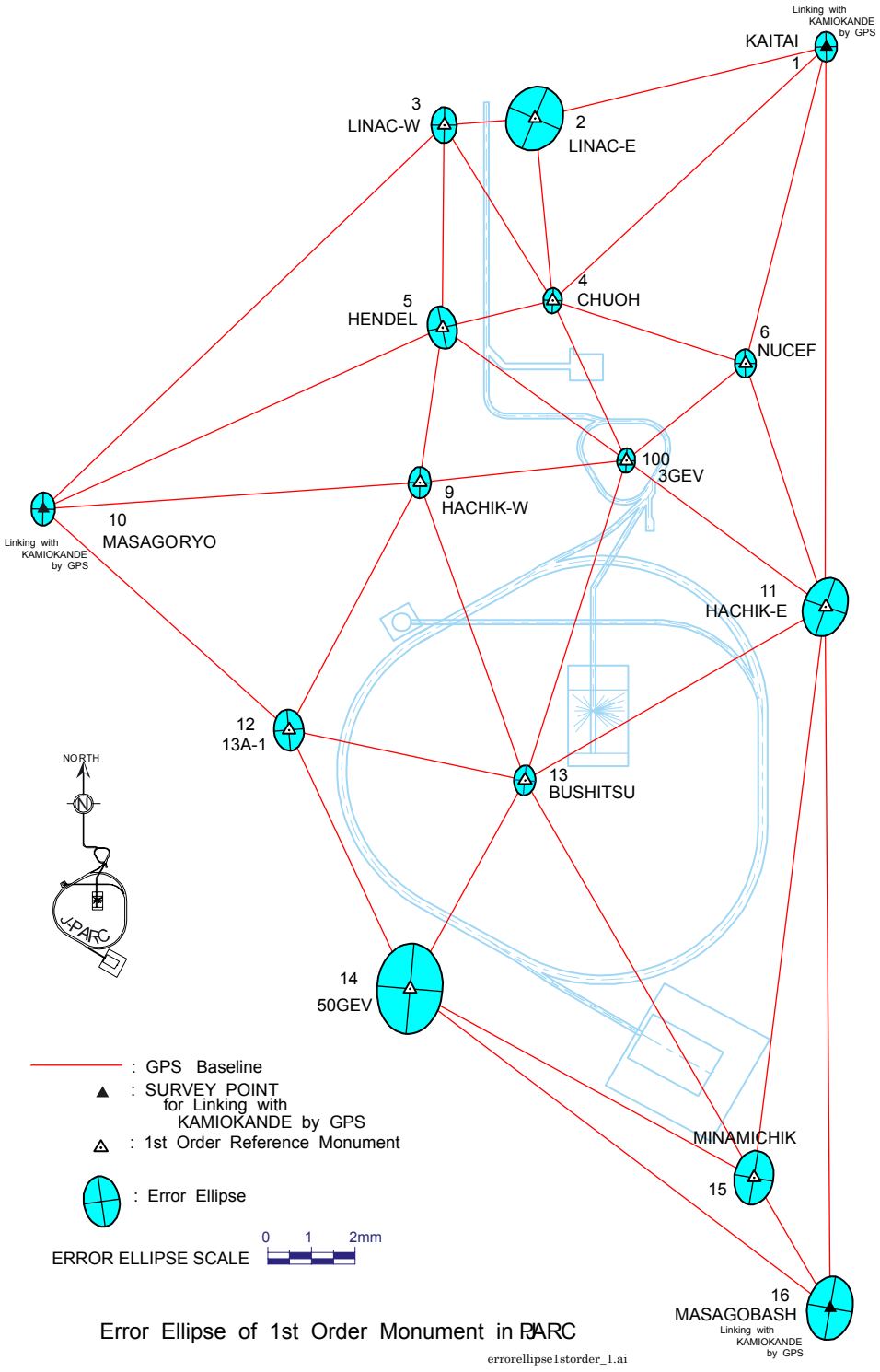


Fig.12 Error Ellipse of 1st Order Monuments in J-PARC

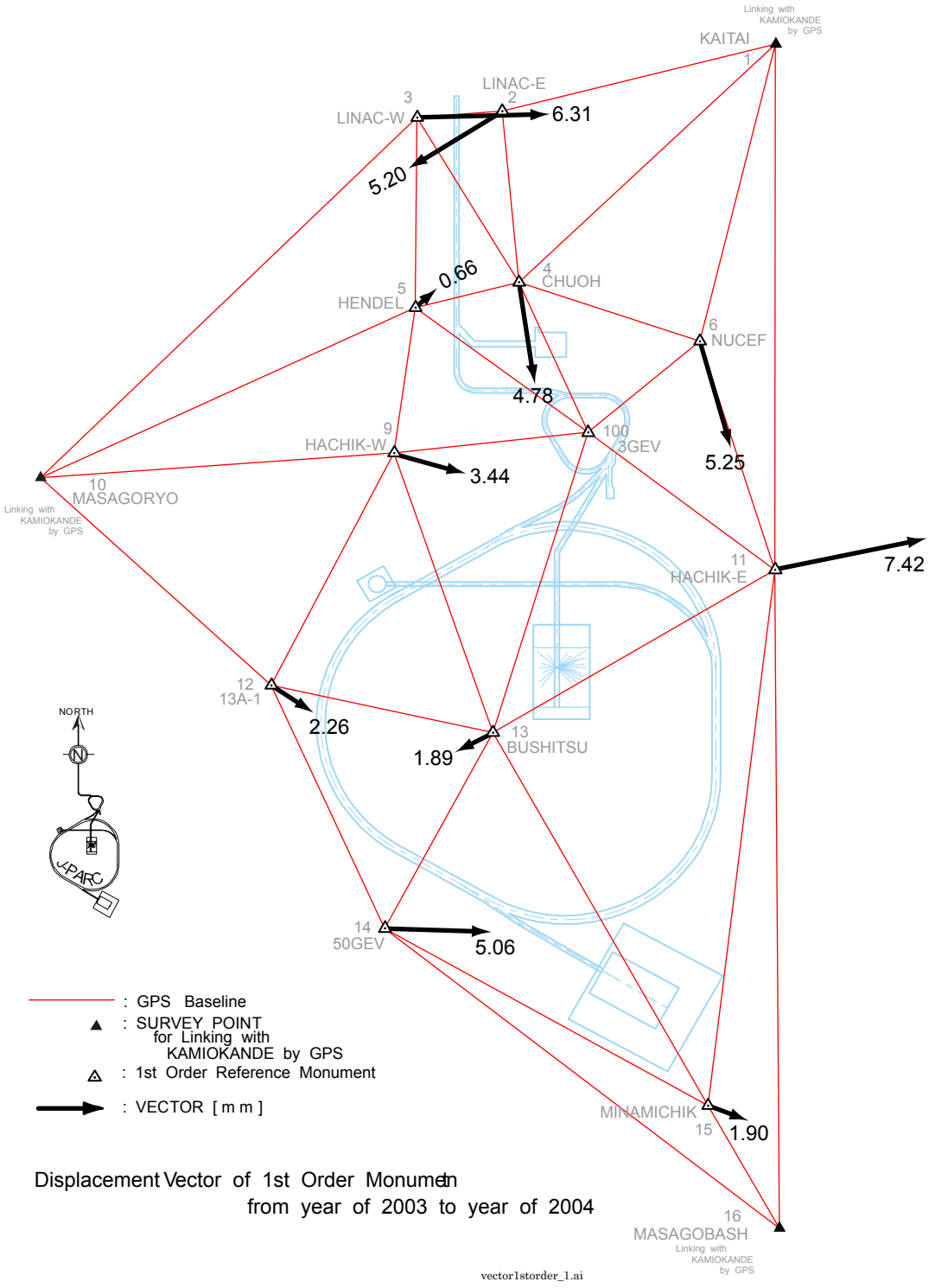


Fig.13 Displacement Vector of 1st Order Monuments from year of 2003 to year of 2004